FULL SCALE ASSESSMENT OF NON-PROPRIETARY PASSIVE NITROGEN REMOVING SEPTIC SYSTEMS

Applicant: Barnstable County Department of Health and Environment (BCDHE)

Partnering with: University of Rhode Island (URI)
The Buzzards Bay Coalition (BBC)
Hazen and Sawyer, Consultant

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Matching Funds: $106,606
Total Project Costs: $835,117

I. Project Description

Onsite wastewater treatment systems (OWTS, or septic systems) will remain a major source of nutrients to coastal marine environments into the foreseeable future. In many marine embayments in Southeastern New England, up to over 80% of the anthropogenic nitrogen comes from this source[1]. Our project will demonstrate the efficacy of using modified Soil Treatment Area (STA; also referred to as leachfield, drainfield, or soil absorption system) designs to remove up to 90%of nitrogen in a passive manner. These designs, recently researched and piloted in other areas of the country[2], are non-proprietary and can be applied to a wide range of

[1] http://www.oceanscience.net/estuaries/reports.htm

[2] *Anderson, D. L., and J. Hirst. 2015. Performance Evaluation of In-ground Passive Nitrogen Reduction Systems. Proceedings of NOWRA/VOWRA/SORA/NAWT Onsite Wastewater Mega-Conference, Uniting for Progress, Virginia, Beach, VA; November 4-6, 2015. www.nowra.org/2015proceedings. National Onsite Wastewater Recycling Association, Alexandria, VA 22314*
Hazen and Sawyer. 2015. Florida Onsite Sewage Nitrogen Reduction Strategies Study: Evaluation of Full Scale Prototype Passive Nitrogen Reduction Systems (PNRS) and Recommendations for Future Implementation. Volume I and II. Final Task B PNRS report submitted by Hazen & Sawyer to Florida Department of Health, Tallahassee, FL.

STAs in southern New England to dramatically improve OWTS performance and reduce nutrient-related water quality problems. This design (Figure 1) places a reactive layer of ligno-cellulose beneath a shallow drainfield to produce a bioreactor containing a profile for successive nitrification and denitrification as shown here. Because they alter the structure of the STA, the proposed designs enhance resiliency of OWTS to climate change so that it is less susceptible to rising water tables.

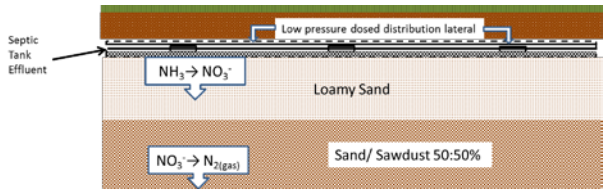

***Figure 1* – Soil profile for Advanced Soil Treatment (AST) unit.**

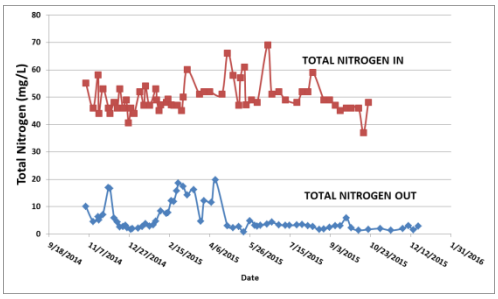

***Figure 2* – Results of pilot AST unit installed at MASSTC.**

The results of pilot systems at the Massachusetts Alternative Septic System Test Center (MASSTC -Figure 2) are promising and corroborate findings of the Florida Onsite Sewage Nitrogen Reduction Strategies Study, the recommendations from which are presently being investigated for implementation by the State of Florida. Should this technique be further validated in our area, it will result in significant cost savings and simplicity of design for area residents who may be required to reduce nitrogen from their OWTS.

Non-proprietary OWTS technologies face a number challenges in both their development and implementation. Foremost, without a commercial interest to drive incentive, research on such systems generally occurs only in academic or research settings. Our proposed work takes advantage of a variety of academic and publically-funded projects that focus on nutrient reduction from OWTS. Using information from these studies and projects, potential designs for reducing nitrogen discharge from OWTS will be refined, installed, and tested *in situ* within the study area.

The implementation of these novel Advanced Soil Treatment (AST) technologies to address the issue of nutrient loading from OWTS involves a range of activities that will proceed in parallel. The unique partnering of scientists (University of Rhode Island-URI), practitioners (URI, Massachusetts Alternative Septic System Test Center-Barnstable County Department of Health and Environment, Hazen and Sawyer) and an advocacy group (Buzzards Bay Coalition) underlies the success and sustainability of the project. The project tasks include: (1) design refinement and adaptation for our geological and climatological setting, (2) identification and recruitment of pilot test sites, (3) local and state permitting, (4) installation at appropriate test sites, (5) testing and validating performance, (6) development of specifications and guidelines that can facilitate the eventual standard approval, and (7) institute a management tool to relieve

the municipalities of the tasks of tracking the various operation and maintenance features of advanced OWTS. Since it is widely accepted that the oversight and management of any installed treatment units are paramount to their success in meeting expected treatment goals, we will employ a highly effective electronic compliance and performance monitoring system developed and presently in use by BCDHE.

The following section details the tasks involved in completing the project, and identify the partners involved. Although numbered below in sequence for easy reference, many of the tasks will proceed in parallel.

Task 1 - Design refinement ***(Heufelder-MASSTC, Amador-URI, Loomis-URI, Anderson and Hirst-Hazen and Sawyer)***
Refinement of the design of selected non-proprietary modifications to the STA has already started. A recent meeting of our partners (Heufelder, Anderson, Amador and Loomis) with researchers and Suffolk County personnel at Stony Brook University, Long Island, New York involved a discussion of improving non-proprietary STA designs to achieve nitrogen reduction. This meeting resulted in the development of three candidate designs to be installed under the present effort. Under separate efforts, Stony Brook University and the Suffolk County New York Health Department will be following our project and conducting research to determine applicability to their area which is directly south of our study area. Damann Anderson and Josefin Hirst (Hazen and Sawyer) will be involved in the initial design phase for our project, and will also serve as a link between the efforts funded under this project with those of Suffolk County. Hazen and Sawyer will also be providing design drawing services.

Final designs presented as a deliverable for the project will be informed by the following activities as they proceed in parallel to other efforts.

> ***Subtask: Elucidation of factors and mechanisms controlling N*** **removal** **(Amador, PhD student).** An understanding of the mechanisms involved in N transformation and removal will allow for system and design adjustments based on known relationship between system parameters and removal processes to optimize performance. To accomplish this, we will carry out the following sub-tasks:
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> a. **Field data analysis.** We will conduct statistical analyses of field data to examine: (i) differences in N removal as a function of STA system design, soil properties, media specifications, and time; and, (ii) relationships between water quality parameter inputs and outputs, electron donors and acceptors, physical variables (e.g. temperature, dosing rate), and N removal as a function of system design and soil properties.
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> b. **Greenhouse gas flux analysis.** We will measure the flux of greenhouse gases (N_2O, CH_4, CO_2) at the ground surface above the AST system as well as the concentration of these gases within the AST system as a function of depth. This information will allow us to examine relationships between chemical, microbial and physical properties of inputs and outputs and gas flux and depth profiles, which will help in identifying the mechanisms by which N is removed.

c. **Experiments using soil and treatment media.** Periodically we will sample soil, treatment media at different depths, and water for analysis of chemical, physical and microbiological properties. These samples will be used to carry out laboratory experiments using ^{15}N-labeled substrates to identify the nature and kinetics of microbial N transformations in the AST systems, and the microorganisms responsible for these transformations. The results will be used to examine relationships among properties of soil and treatment media, microbial variable, system properties, and N removal. This information will further help us establish the mechanisms by which N is removed. Data review will also involve Damann Anderson (Hazen and Sawyer).

These activities will be carried out starting on the last six months of Year 1 and on Years 2, 3 and 4 of the project.

Task 2 - Location of Pilot Test Sites ***(Korrin Petersen-Buzzard Bay Coalition)***

The Buzzards Bay Coalition will identify volunteer property owners in impaired watersheds within the SNEP area by approaching Buzzards Bay Coalition members, working with board of health agents to identify needed local upgrades, and through communication with neighborhood associations. The Coalition will contact property owners, present the project and secure commitments. Identifying participants for this program is modeled on the successful West Falmouth Harbor Shoreline Septic System Remediation Project awarded through the Southern New England Coastal Watershed Restoration Program Nutrient Management Grant program in 2015. There, the Buzzards Bay Coalition secured twenty property owners to voluntarily install nitrogen reducing septic systems capable of meeting 12mg/L total nitrogen or less and have agreed to annual operation and maintenance and a year-long monitoring program.

Participating property owners will be selected based on their location within a watershed that discharges to a nitrogen-impaired coastal waterbody. Specifically, properties within the towns of Acushnet, Carver, Dartmouth, Rochester, Wareham and Westport that discharge within a watershed to a Category 4a water body on the Massachusetts Integrated List of Waters, or a water body with a draft or final Total Maximum Daily Load for nitrogen will be prioritized. The rural character of these communities makes town-wide centralized sewers unlikely, and that OWTS will remain a major component of wastewater infrastructure and source of nitrogen to Buzzards Bay and the rest of Southeastern New England into the foreseeable future. Candidates from Martha's Vineyard communities and the Town of Falmouth will also be considered as those communities have expressed interest in the project.

Twelve test sites (six seasonal and six year-round residences in both moraine and outwash soil settings) will be located. George Heufelder (BCHDE) and George Loomis (URI) will aid in the initial remote screening of sites suitable for the installation of the non-proprietary N-removal treatment systems throughout the study area. Once candidate sites are chosen, we will travel to these sites to witness the prerequisite soil evaluation/percolation tests in order to advise the design engineer/sanitarian regarding optimal placement on the landscape and other design features. This task will be completed during Year 1 of the project.

Task 3 - Local and State Permitting ***(Korrin Petersen-BBC, George Heufelder-BCDHE)***

Permitting will involve both approval by the local board of health and the Commonwealth of

Massachusetts. For property owners committed to participating in the program, the BBC will work with them to obtain State, local board of health, and conservation commission approvals as necessary. Meetings with relevant town boards will be attended by the BBC and other key staff as needed.

This task will also involve working with OWTS designers who may be unfamiliar with certain component descriptions for preparation of the design plan. Assistance in this area will be provided by Damann Anderson (Hazen and Sawyer), who is familiar with design components and permitting. This task will be completed in Year 1 of the Project.

Task 4 - Installation at Appropriate Test Sites ***(George Heufelder-BCDHE, George Loomis-URI, Jose Amador-URI)***

Following site selection, suitability determination and approval, installer guidance will be necessary to ensure proper specification and placement of soil components. This will be conducted by George Heufelder (BCDHE) and George Loomis (URI). In addition, we will also install monitoring ports (pan and suction lysimeters) to monitor system performance. This task will take place in Year 1 – 3 of the project.

Task 5 - Preparation and Submittal of a Quality Assurance Project Plan (QAPP) ***(George Heufelder-BCDE, George Loomis, URI, Jose Amador-URI, Damann Anderson-Hazen and Sawyer)***

A Quality Assurance Project Plan (QAPP) and Quality Management Plan (QMP) will be prepared and submitted during the first six months of the project. This plan will describe all aspects of sampling and analyses to be conducted. This task will involve all project partners and will be submitted by Barnstable County Department of Health and Environment (the major laboratory conducting standard assays required under the Massachusetts Department of Environmental Protection Pilot Approval). URI will submit a QAPP for non-standard assays focusing on process descriptions described above. This task will take place within the first six months of the project.

Task 6 - Development of Specifications and Guidelines ***(Loomis, PhD student, Amador- URI)***

Development of guidelines for the siting, design, installation, and operating and maintenance of these Advanced Soil Treatment (AST) systems is essential for regulatory decision makers to embrace the concept of these new non-proprietary systems and allow their use in the region. We will utilize the project findings, and feedback from practitioners at our outreach activities to describe each of these key elements and to create a comprehensive guideline that will be submitted to the regulatory agencies in the region for their consideration for acceptance as regulatory policy. George Loomis (URI) has a notable track record in completing similar tasks for non-proprietary OWTS technologies and will work closely with regulatory officials to complete this task. This task will take place in Year 2 – 4 of the project.

Task 7 - Communicating Results ***(Amador, Loomis, PhD student-URI, Heufelder-BCDHE)***

To disseminate the results of the study to a broad group of OWTS practitioners, we will present talks, posters and seminars at local, regional and national conferences, including meetings sponsored by the Soil Science Society of America, National Onsite Wastewater Recycling Association (NOWRA), New England Interstate Water Pollution Control Commission (NEIWPCC), and state professional OWTS practitioner associations in the region. Research

results will be published in appropriate peer-reviewed journals (e.g. Journal of Environmental Quality, Ecological Engineering, Water Research). The results of the research will be communicated via outreach workshops, factsheets, and seminars at local, regional and national venues. Educational materials will be prepared in consultation with project partners and will be delivered locally and regionally through the outreach activities of the New England Onsite Wastewater Training Program, through the Buzzards Bay Coalition, as well as through presentations at national conferences. This task will be carried out during Years 2, 3 and 4 of the project.

Task 8- Implementation of an Area-Wide Management Tool for Tracking Performance (Baumgaertel-BCDHE)

It is widely accepted that implementation of advanced OWTS to meet desired contaminant reduction requires a level of oversight and maintenance. This critical aspect is often neglected with disastrous results. Under this task, BCDHE will expand the coverage of its proven electronic operation & maintenance (O&M) and monitoring management tool and assist in its implementation in all municipalities within the project area. Implementation in Barnstable County has resulted in the largest such performance database in the country. BCDHE has used funding of this type in the past to build eventual long-term sustainability of this program. In addition, operation and maintenance tasks can be assumed by any of the communities at the end of the project or alternately they can assign BCDHE to remain the administrator of the program at no cost to the towns; continued monitoring of advanced OWTS is funded by a user fee which is assessed to the system O&M contractor each year. Grant funds will be used to fully subsidize this user fee during the first two years of the project, and subsidize half of the user fee during the third year with the O&M contractor assuming the other half. User fees will be the full responsibility of the O&M contractor starting in the fourth year. This task will be carried out during years 1 through 4 of the project.

II. Environmental Results

The progress of these efforts will be tracked using both quantitative measures and qualitative progress using the intermediate and final outputs (Table 1). **This project advances the SNEP Priority 1 by implementing innovative cost-effective practices to reduce the impacts of wastewater-derived nutrients. The main outcome of the project will be the incorporation of this non-proprietary soil-based treatment strategy into the wastewater management strategies of the communities that rely on OWTS for treatment and the deployment of an electronic operation & maintenance (O&M) and monitoring management tool in a number of towns located within the SNEP area**. The results of our project will shift the focus from advanced proprietary treatment strategies to soil-based treatment components, which are passive, sustainable and, in some instances, superior to proprietary manufactured units. As the data emerge and costs per pound of nitrogen removed calculations are made, there will be more information available for evidence-based decision making.

Data from the advanced soil treatment (AST) systems and the other advanced OWTS captured in the expanded management portion of the effort will be published on a data sharing website associated maintained by the Barnstable County Dept. of Health and the Environment

(http://www.barnstablecountyhealth.org/resources/data-and-statistics/ia-septic-system-data). Combined, these data will provide an unprecedented level of analysis for watershed and wastewater management efforts which endeavor to predict nitrogen loads under various onsite wastewater management scenarios. Specifically, these data will allow decision makers to calculate actual nitrogen load reductions to the watersheds from these installations. Coupled with land use analyses, these data can be used to estimate a total load reduction in other watersheds as a function of the technology used, including the proposed non-proprietary STA design. Our study will also produce peer-reviewed publications that will facilitate acceptance of the technology by regulatory and decision-making entities, and develop a better understanding of how this novel design works, its performance in the context of existing leachfield designs, and its transferability to other landscapes.

Project Outputs			
Task	**Description**	**Measure**	**Period**
1	Design refinement	The number of candidate designs and the experiments conducted to validate the efficacy of these designs in achieving desired goal	Year 1-4
2	Location of pilot sites	Number of sites investigated and successfully vetted for use Number of communications with potential pilot site owners Number of community/informational meetings	Year 0-1
3	Local and state permitting	Regulatory board application hearings attended (conservation commission and board of health) Local approvals filed and obtained State approvals filed and obtained	Year 0-1
4	Installation of technologies	Number of technology installations Number of inquiries regarding technology	Year 0-1
5	Preparation of QAPP and sampling	Successful completion of QAPP Number of samples taken	Year 1-3
6	Development of Guidelines	Consensus meetings with regulatory officials Guidance document completion	Year 2-3
7	Communicating results	Number of technical papers presented Number of peer reviewed papers published	Year 2-4
8	Implementation of an Area-Wide Management Tool for Tracking Performance	Number of board of health rule change hearings attended Number of local regulations passed requiring tracking Number of training sessions conducted Number of compliance checks conducted Sustainability attained Website access broadened and data sharing (website inquiry numbers) Number of assists for compliance Number of discharge data points collected	Year 0-4

Table 1. List of outputs to be used for evaluation of progress during the project.

III. Transferability of Results and Collaboration Across the SNEP Area

The STA designs to be researched represent a simple, sustainable practice that can be widely applied across the SNEP area and other coastal areas. A number of the project partners are already collaborating with Long Island researchers and Suffolk County personnel, with similar goals. Our inquiries for support have shown a very high level of interest from many municipalities (Acushnet, Carver, Dartmouth, Wareham, Westport, and Martha's Vineyard) and environmental advocacy groups (Nature Conservancy, Buzzards Bay Coalition). The partnership with Rhode Island experts in this area, which is a natural outcome of many previous associations and communications in the area of OWTS between the two major partners in this project, will help further the transference and acceptance of the study findings at the regional scale.

IV. Partnerships

The partners in this project have established longstanding associations which would predict a high degree of success. Barnstable County and the main investigator at Hazen and Sawyer (Damann Anderson) have, for the past two years been collaborating on design features of successful systems and have been in regular contact regarding results from pilot systems installed at the Massachusetts Alternative Septic System Test Center (MASSTC). George Heufelder (BCDHE and MASSTC) has been in regular contact over many years with George Loomis (URI) who is a highly-respected, well-published Soil Scientist and practitioner in OWTS design and research. Many of his publications are co-authored with Jose Amador PhD (URI), and these two researchers work closely together from the same institutional area. The Buzzards Bay Coalition participant (Korrin Petersen, Esq.) has worked closely with George Heufelder on the implementation of a watershed protection program in Falmouth, Massachusetts on a project installing 20 proprietary and non-proprietary systems in the West Falmouth Harbor Watershed. Brian Baumgaertel (BCDHE) has been working with George Heufelder for five years in the refinement and development of the tracking mechanism for advanced OWTS. These previous working and professional relationships serve as a basis for predicting success. The participant's specific roles can be summarized as follows:

George Heufelder and Brian Baumgaertel (BCDHE) – Will provide overall coordination of the field sampling and data synthesis as well as the implementation of the management tool referenced. George Heufelder will compile and submit the QAPP.

Korrin Petersen, Esq. (BBC) – Will identify and recruit volunteer sites for system placement and facilitate local and state approvals.

Dr. Jose Amador (URI) – To oversee the research efforts of a PhD student regarding the various aspects of nitrogen transformations in the new layered system, use data from field sites, laboratory experiments, and statistical analysis to elucidate the factors and mechanisms that control N removal, communicate the results of the study to scientists, regulators and practitioners and develop guidelines for the siting, design, installation, and operation and maintenance of Advanced Soil Treatment (AST) systems.

George Loomis (URI) – Will aid in the identification of sites suitable for the installation of the non-proprietary N-removal treatment systems throughout the study area. Once a short-list of

potential sites has been identified, we will travel to these sites to provide advice on the suitability of the soils and landscape for system installation. We will also provide technical assistance relative to AST system installation as necessary. This task will be completed during the first six months of Year 1 of the project. Will compile guidance documents for design and work with state regulators on implementation if indicated by pilot testing.

Damann Anderson, P.E. and Josefin Hirst (Hazen and Sawyer) – Will provide consulting services on system design, data review, and design guidance. Mr. Anderson has considerable experience in developing design guidance for OWTS technologies, and is currently assisting Florida in that effort for the layered soil treatment system approach. He is also currently the director for a project with Stony Brook University to evaluate nitrogen reducing OWTS technologies, and recently led a design charrette to establish design criteria and testing plans for layered soil treatment systems on Long Island.

V. Programmatic Capability and Past Performance.

The partners in this project all have longstanding records of success in their respective roles. George Heufelder with Barnstable County Department of Health and Environment was instrumental in forming and directs the Massachusetts Alternative Septic System Test Center which assists the industry and regulators in testing new and innovative technologies. He has completed numerous projects funded the Federal Clean Water Act Section 319(b) Competitive Grant Program concerning septic systems including issues of nitrogen and phosphorus removal, removal of Contaminants of Emerging Concern in soils-based treatment, investigation of non-proprietary systems for the removal of nitrogen, the removal of viruses in OWTS and others relating to the development of training tools for local boards of health.

George Loomis of the University of Rhode Island is a Research and Extension Soil Scientist and the Director of the New England Onsite Wastewater Training Center. He has thirty-one years of experience in siting, design, operation and maintenance, and research and education in conventional and alternative OWTS. George directed state and federally-funded demonstration projects installing nearly 60 alternative N removal technologies in RI, and is a member of the Rhode Island DEM Technical Review Committee. George co-developed the Rhode Island sand filter guide, bottomless sand filter guide (also used in Massachusetts and Vermont), and the pressurized drainfield guide.

Jose Amador of the University of Rhode Island is a Professor of Soil Science and Microbial Ecology. He has conducted research on the biogeochemistry and microbial ecology of soil-based wastewater treatment systems for the past 13 years. Jose's research in this area has been funded (~$1,000,000) by federal, regional, state and private entities. This has resulted in more than two dozen peer-reviewed papers, as well as numerous invited presentations to scientists, practitioners, regulators and the general public at the state, regional and national level. Jose and his graduate students work closely with George Loomis in the translation of research results to outreach education materials.

Damann Anderson and Josefin Hirst with Hazen and Sawyer have conducted similar research, development and demonstration studies of alternative, nitrogen reducing layered soil treatment systems as part of the Florida Department of Health's comprehensive nitrogen reduction

strategies project. The knowledge and experience gained through the Florida project will aid in the development of similar systems for evaluation in southern New England as part of this project. In addition, Mr. Anderson has considerable experience in developing design guidance for OWTS technologies, and is currently assisting Florida in that effort for the layered soil treatment system approach. He is also currently the director for a project with Stony Brook University to evaluate nitrogen reducing OWTS technologies, and recently led a design charrette to establish design criteria and testing plans for layered soil treatment systems on Long Island.

Korrin Petersen, Esq. is a Senior Attorney with the Buzzards Bay Coalition. In this capacity, she has guided a similar effort as proposed in the West Falmouth Harbor Watershed and has been successful in obtaining Piloting Approvals in the Commonwealth of Massachusetts.

Brian Baumgaertel with BCDHE developed the web-based tracking and reporting system and has assisted all of the Barnstable County towns and others in the SNEP Area to implement a sustainable management system for advanced OWTS. It is presently the largest such database in the country and is being used for statistical comparisons to aid the EPA Data Sharing Effort.

VI. Budget Narrative

The nature of this project, which is subject to a recruitment process and at least two approval processes, makes the precise timetable for expenditures difficult to predict. Under favorable conditions as indicated by the interest of the municipalities involved, the local approval process should allow for the following estimated apportionment of funds over the four years of the project. Implementation costs ($180K total, $120K requested, $60K match) should be expended in Year 1 and 2. Cost associated with the approval processes (BBC – Korrin Petersen's time, Hazen and Sawyer time) will similarly be weighted toward the beginning of the project during the recruitment and approval processes. The tracking management system time will be weighted toward the earlier part of the project since staff must work with boards of health and conduct local efforts such as training during this period. Sampling costs (analyses, travel, staff) are weighted toward years 2-4 when systems will be in the monitoring phase of the project. University of Rhode Island "Graduate Stipend" also includes support supplies and travel – these are not detailed due to uncertainty as to the frequency with which analyses sampling and analyses will be performed and the amount of travel to research sites that will be required. George Heufelder will coordinate all activities and ensure the timely execution of tasks.

VII. Timely Expenditure of Grant Funds

Although progress is subject to an unpredictable recruitment and approval process, there has been much support expressed and many inquiries ahead of the project start that suggests that the recruitment and approval process can take place in the first 18 months. Following this, all elements of the project are similar to sampling endeavors similar to those routinely carried out by all the partners in this project. As research questions arise, we believe that efforts of the PhD student under Dr. Amador will experience no delays and move forward in the required timeframe. Quarterly progress reports and regular telephone conference calls will ensure that all project components will be completed in a timely manner. When obstacles arise, the coordinator of the project, BCDHE staff will convene a conference call to resolve difficulties.